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(56) Documents Cited:
GB 2254801 A **GB 2110803 A**
CA 002038651 A **US 5869817 A**
US 5400524 A **US 4608261 A**

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INT CL[7] **B65G, H05B**
Other: **WPI, EPODOC**

(54) Abstract Title: **Screw conveyor with microwave generator**

(57) An apparatus comprises a rotatable auger 10 with an impervious shield 11 and microwave generating equipment 16 disposed to heat material transported lengthwise by the auger within the shield, wherein there is provision for extraction of liquid and/or escape of gas 18 from within the shield. The auger and the shield are formed or coated using microwave non-absorbent substances. Multiple microwave generators may be provided along the length of the shield, wherein at least two have individual controls for regulating electrical supply. The speed and direction of the auger may also be controlled while the position of the microwave generating equipment may be changed relative to the shield. Discrete parts of the shield may comprise a substance transparent to microwaves. A method of using the apparatus for reclaiming matter and/or energy from waste or other raw material in solid form optionally in the presence of a liquid, e.g. through pyrolysis, is also disclosed.

Fig.1.

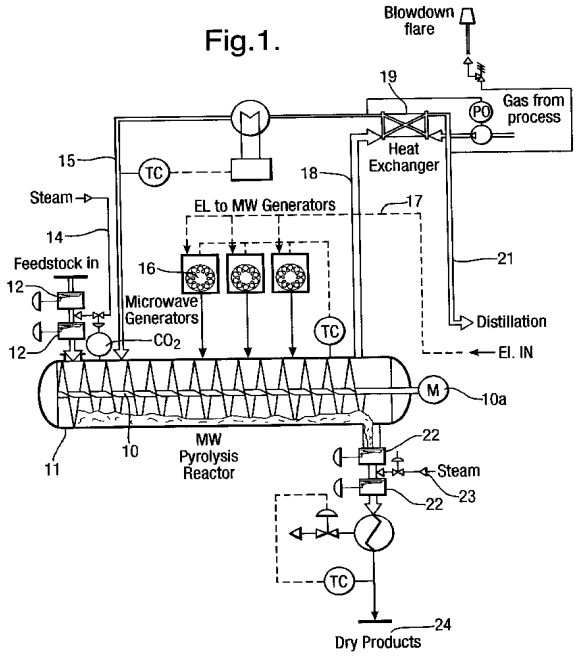

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Fig.1.

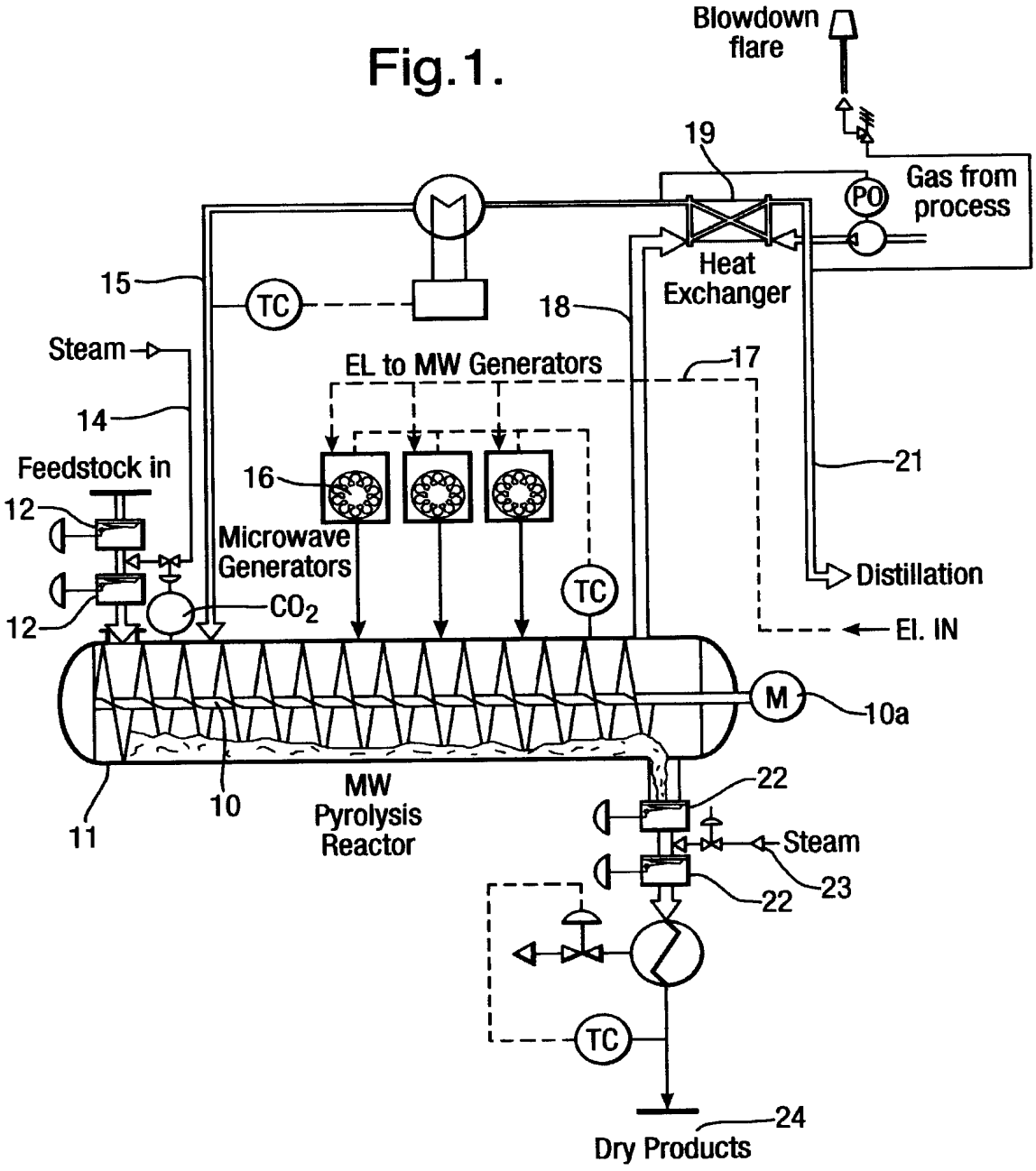
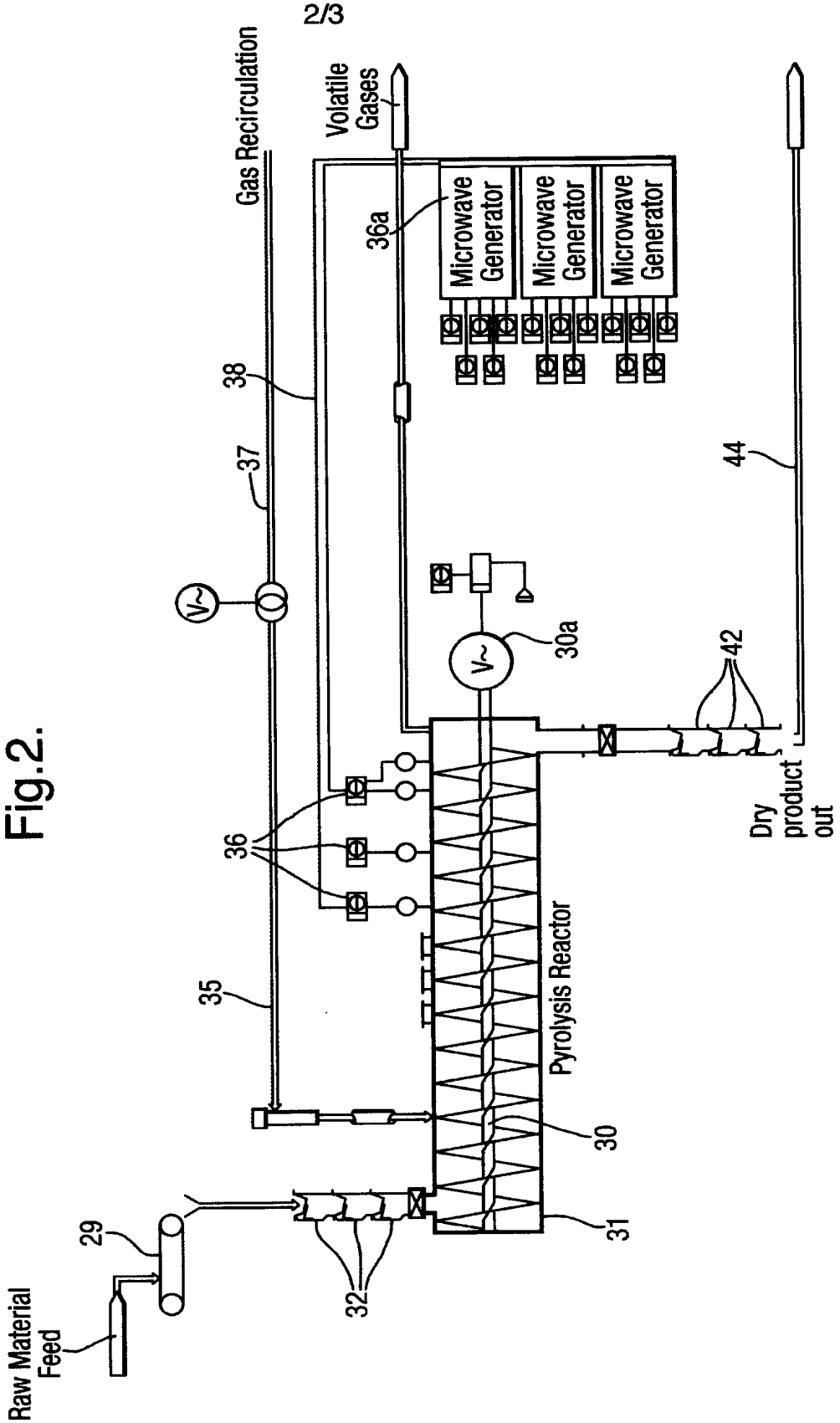

Blowdown flare
19
Gas from process
PO
Heat Exchanger
15
TC
18
Steam
EL to MW Generators
17
14
Feedstock in
16
21
12
Microwave Generators
Distillation
12
CO_2
TC
El. IN
M
10a
11
10
MW Pyrolysis Reactor
22
Steam
23
22
TC
24
Dry Products

Fig.2.


Gas Recirculation
Volatile Gases
Microwave Generator
Microwave Generator
Microwave Generator
36a
38
37
44
V~
30a
42
36
Dry product out
35
Pyrolysis Reactor
30
31
29
32
Raw Material Feed

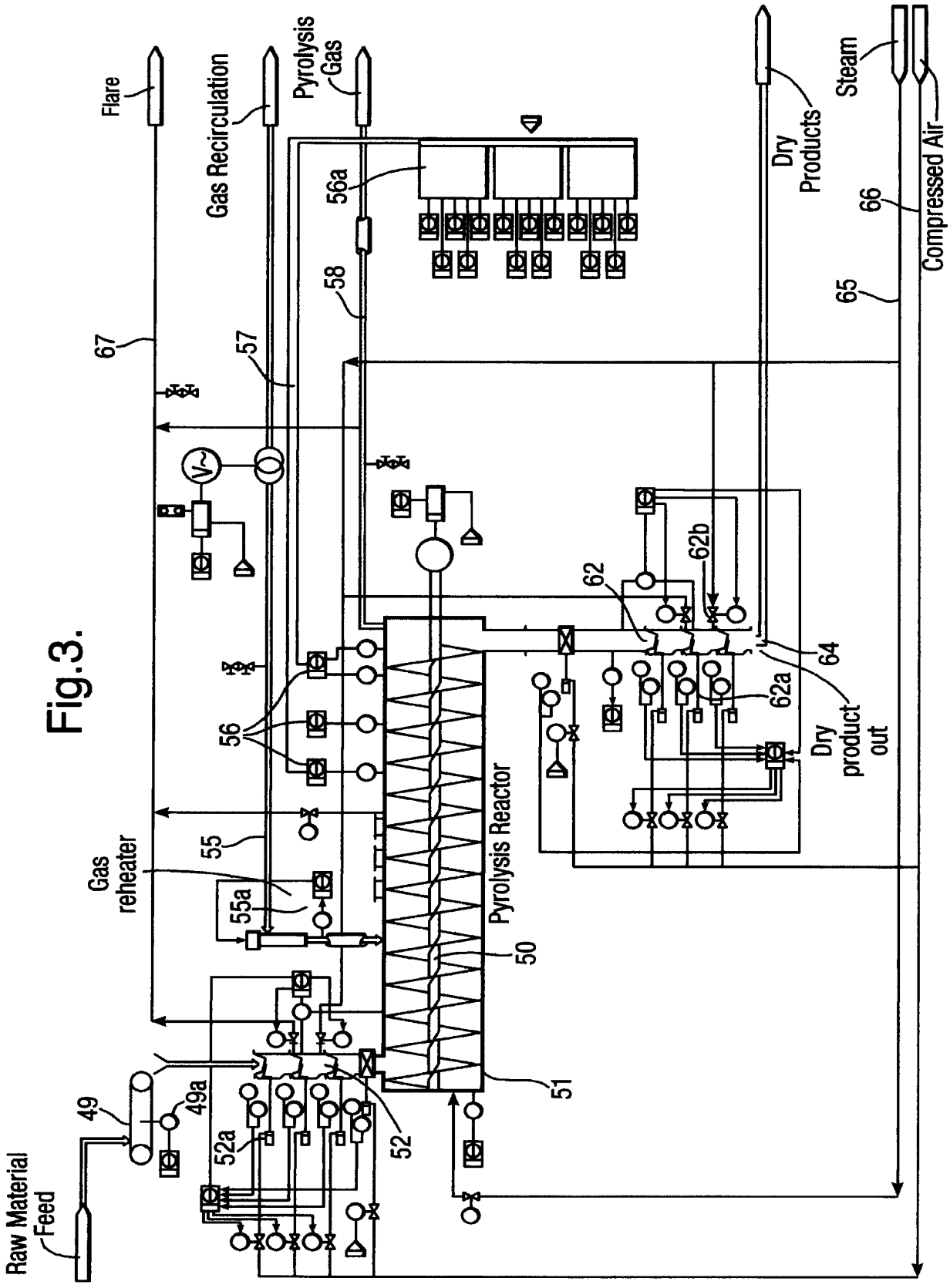

Flare
Gas Recirculation
Pyrolysis Gas
Dry Products
Steam
Compressed Air
Raw Material Feed
Gas reheater
Pyrolysis Reactor
Dry product out
49
49a
50
51
52
52a
55
55a
56
56a
57
58
62
62a
62b
64
65
66
67

Fig.3.

MICROWAVE TREATMENT OF MATERIALS USING AN AUGER

The invention relates to microwave gasification, pyrolysis and recycling of waste (including organic materials).

BACKGROUND OF THE INVENTION

The recycling of different materials and the conversion of the energy contents of waste becomes ever more relevant and the target of large scale investments, private as well as public. The procedure used normally is to pre-sort those materials found in the municipal waste which may be recycled. What remains are materials that may be converted into energy through, for example, incineration.

The problem of waste accumulation grows steadily. It is expensive both in terms of collection costs and fees charged and are particularly unacceptable in terms of the valuable resources that are wasted.

Incineration is the more common of the methods for retrieving the energy from waste that can not be recycled. The energy is usually converted into heat in the form of hot water or steam that subsequently may replace "nobler" forms of energy.

Hierarchically, electricity in the form of alternating current is the most valuable form of energy, as it may, at low cost, be converted into practically any other form of energy.

The cost of converting the energy contents of waste into electric power through incineration is, however, very high, usually requiring large plants if conversion is to yield a good financial return. The high costs are the result particularly of very strict public regulations regarding the releasing of polluting emissions into the atmosphere.

Pyrolysis is known traditionally as the conventional retort dry distillation process utilising an external source of heat, sometimes combined with partial combustion of the contents in the retort. Examples of such processes are the production of wood-tar/charcoal and coke from wood and coals respectively. In modern plants, pyrolysis may be best known as what the petrochemical industry refers to as "cracking."

Even after the invention of the magnetron in 1921, which used radio tubes to create the microwaves (MW), it took a quarter of a century before MW generators reached the market and came into practical use. In the post-WWII period, MW processes have found multiple applications within industries and in private households.

STATE OF THE ART OF MW TECHNOLOGY

MW technology allows for the conversion of waste into electricity and other energies in smaller units than incineration because of the minute quantities of air involved in the process. This results

in considerably smaller volumes of gasses and vapours per unit of energy gained, as compared with incineration.

Pyrolysis is the equivalent of dry distillation and involves the decomposition of materials at a precisely controlled temperature, without or with precisely controlled quantities of oxygen, air or other additives for the enhancement of the process. This enables the extraction of valuable chemicals from the waste that would otherwise have been destroyed had the waste been burned.

The fractionated component materials that may be obtained through pyrolysis fall roughly into five categories.

1 – **Non-condensing volatile gas**, which in many cases may be utilised directly as fuel in an IC engine/gas turbine to generate electricity after only simple cooling, rinsing and filtering.

2 – **Liquids**, which may be utilised as fuel oils or after, fractional condensation, may represent raw materials of interest to chemical industries.

3 – **Carbon.** This is the charred end product of organic waste which may be further processed into activated charcoal, be utilised as a reducing agent in metallurgical processes or be used as a very energetic solid fuel whose flue gas emissions are exceptionally clean.

4 – **Metals,** such as the metal cording from shredded automobile tires, will after MWP maintain their strength and resilience and may be added to reinforced concrete or plastics. Had the steel been exposed to ordinary incineration, it would have become oxidised and would thereby have lost its value both as an additive and as a raw material. Copper from electric cables and metals from electronic waste are other examples of recovered metal.

5 – **Ashes.** Metals and minerals may in many instances be re-circulated by being separated from the ash fraction after MWP. Examples of such recycling are the recovery of chrome from tanning industry waste and of silver from exposed x-ray films.

The disadvantage of conventional dry distillation or pyrolysis is, however, that, for the most part, the heat for the raw materials must come from outside the retort. This delays the heat transfer and leads to uneven decomposition temperatures inside the retort.

In MWP the heating takes place by volume inside the raw material or the waste itself. Thus, a considerably more efficient conversion may take place as compared to retort pyrolysis. The process temperature may be controlled to within narrow parameters. The state of the art is such that retort pyrolysis by batch as well as continuous MWP using linear conveyors is available technologies.

The known methods are, however, relatively inflexible if the raw material is of varying consistency and properties. Certain materials resist being heated as they will not absorb MW. These materials have to be heated indirectly, often by mixing shredded MW-inert material together with MW-absorbing material such as carbon, or other MW-reactive materials.

Decomposition of materials and MW absorbing waste through MWP has been known for many years, and is referred to in various details of several patents, such as: US-3,843,457 & US-5,330,623.

Fractional condensation for the extraction of volatile and liquid components is referred to in patent US-3,843,457

Mixing of materials that do not absorb MW with granulated carbon or other MW absorbent materials is referred to in Norwegian patent application: NO-1995,2652.

Preheating of raw materials with infrared light (IR), prior to MWP is referred to in US patents: US-5,084,141 and US-4,647,443.

The use of inert gas in the pyrolysis chamber to prevent oxidisation of the raw materials is referred to in US patent: US-5,084,141.

A straight conveyor for the transport of the raw materials for decomposition through a tunnel is likewise referred to in the US patent: US-5,084,141.

Full or partial use of volatile, flammable gas components from MWP for the preheating of raw materials or wastes is referred to in US patent: US-5,084,141.

The generating of electricity through the use of volatile flammable gases used directly as motor fuel after filtering has been described in several sources and has been utilised in industrial processes.

MW technology has been, is and will be used in such industrial plants and processes as:

- The sterilising and/or destruction of infectious material as: prions, fungi spores, viruses, bacteria and other undesirable micro-organisms.

- The sterilising and/or decomposition of liquid organic waste such as: sludge from sewage plants, and oil-polluted sludge from petrochemical drilling.

- Recovering of metals, salts or minerals, such as chrome from tanning industry waste.

- Recycling and recovering of waste components found in municipal wastes such as: energy, plastics and glass.

- Decomposition or destruction of "problem waste", such as: PCB, dioxin, anti-fouling for ships hulls, paints, etc.

- Recycling of chemicals and energy from plastics and rubber products, such as: automobile tires and electronic products
- Energy production from compressed agricultural waste, such as: straw.

- Hardening processes for organic adhesives, steels and different mineral compositions.

- Welding operations for thermoplastics.

SOME SPECIAL ADVANTAGES OF THE MW TECHNOLOGY:

The starting up and closing down of the processes are instantaneous.

The heating takes place by volume inside the material, not from the outside.

The process temperature may be controlled to within narrow parameters.

No catastrophe can result in case of a power failure as the materials in process will simply rest until power is restored.

The risk of fire or explosion in the resulting gases is greatly diminished due to there being only a minimal amount of air present during all stages.

In all forms of the incineration, gasification and pyrolysis of waste, the control of critical parameters is both important and at the same time complicated. This applies to the process itself as well as to issues of temperature, false air, fire and explosion risks, radiation and emissions into the atmosphere, run-off into rivers lakes and oceans, just to name a few.

Among the various waste handling processes, MWP holds many potential advantages. For example, because the amount of air is minimal, little or no fly ash and flue gases need to be filtered, cleansed or scrubbed, removing thereby the need for costly equipment and additives.

DISADVANTAGES WITH THE STATE OF THE ART

It may appear after the above summary that MWP is a fully developed technology and that there no longer is room for improvement. That, however, is only how it seems at first glance. If one hoped to acquire full scale equipment for, for example, the treatment or decomposition of larger quantities of tar impregnated railway sleepers or for the recycling of automobile tires on a large scale, one would discover that there is no such commercially operative equipment available to treat these problematic wastes, none with the capacity adapted to the magnitude of the problem.

SUMMARY OF THE INVENTION

According to the invention, microwave pyrolysis is utilised in a process where the material to be treated is brought into an auger conveyor system consisting of one rotating screw, or spiral, in a closed tube, or several auger conveyor type conveyors enabling the transporting of the raw material, thus enabling a varied predetermined treatment program for each auger conveyor or quantity of material. The transportation may take place at different speeds, continuously or intermittently or halted or even in reverse. Along the linear conveyors are placed stations for specific equipment that will be programmed to give individualised treatment to the various auger conveyors, said materials. To obtain an inert atmosphere when desired, appropriately small quantities of water are injected into the auger conveyor, said the protecting tube that surrounds the screw. Further auxiliary equipment is positioned for the programmed sluicing in and out of the various auger conveyors of specialised treatments. The volatile gases are led out of the pyrolysis zone for further treatment or to fuel internal combustion engines or gas turbines for the production of electricity, while the vapours are led into fractional condensation in a separate column. The residue in the auger conveyor or auger conveyors, usually in the form of charred organic matter, may be utilised as fuels or raw material for later activation or reduction purposes.

STATEMENT OF INVENTION

The invention provides apparatus for the reclamation of matter and/or energy from waste or other raw material in solid form or as a liquid in combination with solid material acting as a soaking bed; through the use of microwave induced pyrolysis or evaporation, and comprising an auger within a generally impervious shield, provision to introduce material at or near one end of the auger, means to rotate the auger at will to move material lengthwise within the shield, microwave generating equipment disposed to heat the material as the material moves lengthwise within the shield, provision for the removal of residual solids at or near the other end of the auger, and provision for the extraction of liquid and/or to allow the escape of gas from within the shield, in which the auger and the shield are formed of, or coated with, non-absorbent substances.

It is preferred that there is a plurality of microwave generating equipment disposed along the length of the shield.

It is further preferred that there are individual controls to regulate the electrical power supplied to at least two of the plurality of microwave generating equipment.

It is also preferred that the position of the microwave generating equipment can be changed relative to the shield.

In this form it is further preferred that there are standard fitments on the outside of the shield whereby different arrangements of microwave generating equipment or other ancillary machinery can be fixed relative to the shield.

There may be means to control the speed and/or direction of rotation of the auger.

In one form there is means to introduce controlled quantities of water to the material before the material is introduced to the auger.

Alternatively or additionally there is means to introduce controlled quantities of water to the material at or near the provision to introduce material to the auger.

It is preferred that there is means to add catalysts in solid, pelletized or liquid form to material entering the auger, where by the catalysts are mixed with the material by the action of the auger.

Discrete parts of the shield may be formed of a substance which is transparent to the passage of microwaves.

It is preferred that there is provision to sluice out processed material from the auger and the shield surrounding the auger.

Advantageously there may be two or more such apparatus arranged to run in parallel.

The invention includes a method for the reclamation of matter and/or energy from waste or other raw material in solid form or as a liquid in combination with solid raw material, acting as a soaking bed, comprising the steps of feeding the material to an auger within a generally

impermeable shield at or near one end of the auger, the auger and the shield being formed of, or coated with, non absorbent substances, rotating the auger to move the material lengthwise within the shield, applying microwave energy to heat the material as the material moves lengthwise within the shield, removing residual solids from the shield at the other end of the auger, and extracting liquid and/or allowing the escape of gas from within the shield.

DESCRIPTION OF THE DRAWINGS

Three specific embodiments of the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is an illustration of a pyrolysis reactor in accordance with the invention;

Figure 2 is a process diagram of a second pyrolysis reactor; and

Figure 3 is a process diagram of a third pyrolysis reactor.

SPECIFIC EMBODIMENTS OF THE INVENTION

As shown in Figure 1, a microwave pyrolysis reactor comprises an auger 10 is mounted for rotation within a generally impervious shield 11. The auger 10 is driven by a motor 10a. The auger 10 and shield 11 are formed of a substance which does not absorb microwaves, or may be coated with such a substance. At the left hand end (as shown) of the auger 10 there is an assembly of airlocks 12 above the shield 11. The airlocks 12 are arranged so that raw material can be introduced into the left hand end of the shield without permitting the admission of air. However, there is a valve 14 arranged to admit steam between the airlocks in the event that steam is desirable to enhance the process of pyrolysis.

Rotation of the auger 10 moves material lengthwise within the shield 11 from left to right. Optionally, there is a line 15 through which process gas can be admitted to act on material within the shield.

Following the invention, there are multiple microwave generators 16 disposed along the top of the shield 11. These act through discrete parts of the shield which are transparent to microwaves. There may be provision (not shown) to change the arrangement of the microwave generators relative to the shield. The microwave generators are supplied by connections 17 from any convenient external source of electricity. Action of microwaves on material within the shield drives off gases by pyrolysis. These gases can be allowed to escape from the shield through pipework 18, leading to a heat exchanger 19. As the incoming process gas for line 15 is heated, liquids may be condensed by cooling. The resulting liquids can be passed through line 21 to further distillation processes forming no part of this invention.

At the left hand end of the shield 11, and lying below the auger 10, there are further air locks 22. These airlocks 22 are arranged to allow removal of material from within the shield after to process of pyrolysis has been completed. Steam may be introduced between the airlocks by valve 23. Dry products from the process drop out of the apparatus at 24.

A second embodiment of the invention is shown in Figure 2. In this embodiment an auger 30 is mounted for rotation within a generally impervious shield 31. The auger 30 is driven by motor 30a. At the left hand end (as shown) of the auger 30 there is an assembly of airlocks 32 above the shield 31. The airlocks 32 are fed with raw material from a conveyor 29, and allow material to enter the shield below. Recirculated gas may be admitted to the inside of the shield 31 through line 35.

Following the invention as before, multiple microwave ports 36 are disposed along the top of the shield 31. Connections 37 lead to microwave generators 36a. Action of microwaves on material within the shield drives off gases by pyrolysis. These volatile gases leave the apparatus through pipework 38.

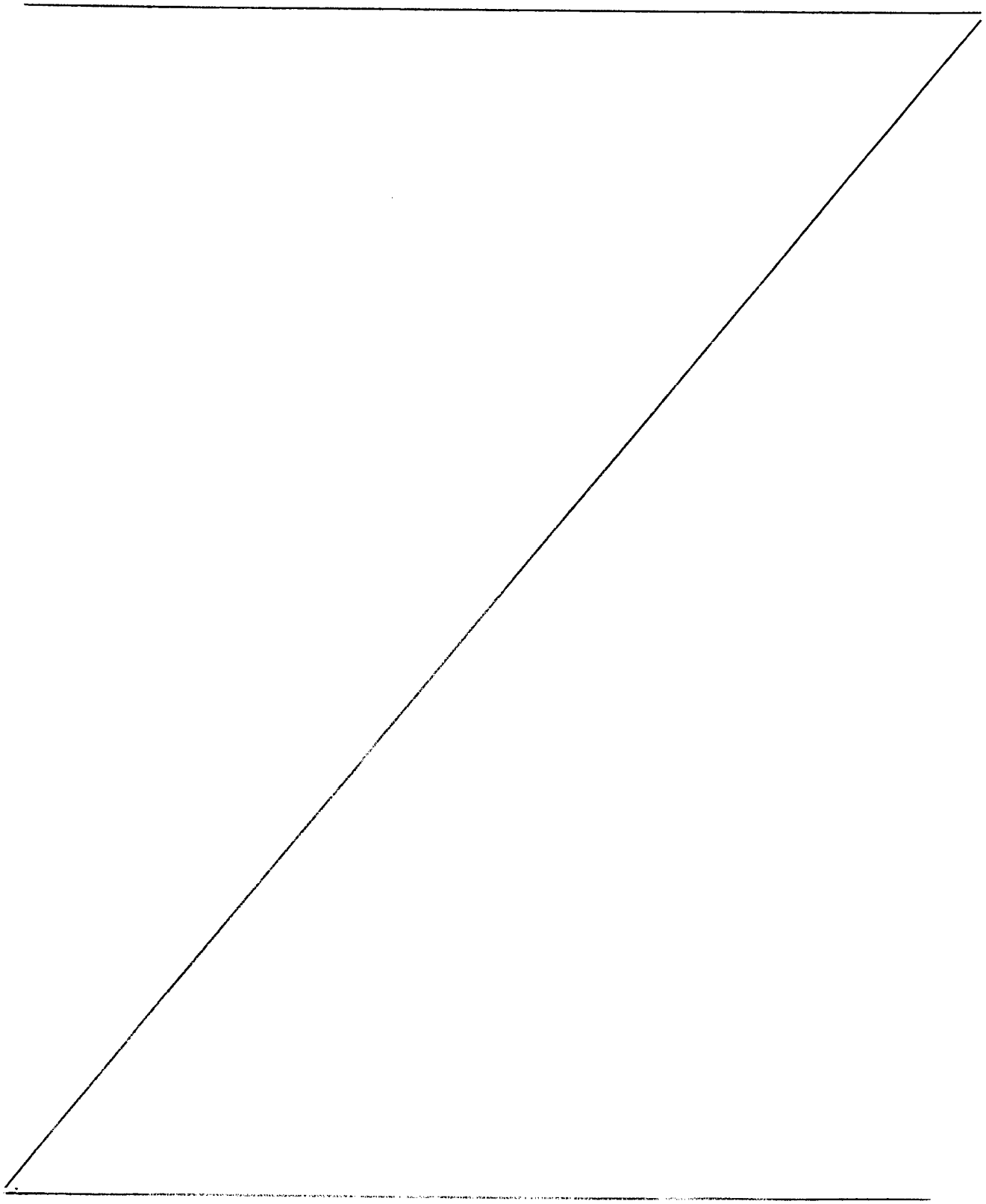
At the left hand end of the shield 31 there are three further airlocks 42. These airlocks 42 are arranged to allow removal of material from within the shield after the process of pyrolysis has been completed. Dry products from the process drop out of the apparatus at 44.

A third embodiment of the invention is shown in Figure 3. This adds illustrations of several optional features to the embodiment shown in Figure 2. In this embodiment an auger 50 is mounted for rotation within a generally impervious shield 51. At the left hand end (as shown) of the auger 50 there is an assembly of airlocks 52 above the shield 51. The airlocks 52 are fed with raw material from a conveyor 49 (driven by motor 49a), and allow material to enter the shield below. In this embodiment there are several valve mechanisms 52a through which catalysts or other additives can be introduced to the incoming material before it reaches the auger 50. Recirculated gas may be admitted to the inside of the shield 51 through line 55. In this embodiment a gas reheater 55a is included to heat the recirculated gas.

Following the invention as before, multiple microwave ports 56 are disposed along the top of the shield 51. Connections 57 lead to microwave generators 56a. Action of microwaves on material within the shield drives off gases by pyrolysis. These volatile gases leave the apparatus through pipework 58.

At the left hand end of the shield 51 there are three further airlocks 62. These airlocks 62 are arranged to allow removal of material from within the shield after the process of pyrolysis has been completed. Dry products from the process drop out of the apparatus at 64. In this embodiment, additional connections 62a are in place to admit compressed air to the outgoing airlocks 62. Further connections 62b are in place to admit steam to the outgoing airlocks 62. Compressed air and steam lines 65 and 66 respectively are in place to supply the extra connections 62a and 62b.

In this embodiment there is provision, in the form of line 67, for gases driven off the raw material by the pyrolysis to be flared by means forming no part of this invention.



DESCRIPTION OF THE INVENTION IN ITS PREFERRED EMBODIMENT

This invention is developed to solve a series of the practical difficulties that are encountered in the presently available systems for MWP. Special focus is aimed at the concentrating and precise controlling of the processes beyond present day possibilities, whether these are intermittent or continuous.

The principle of the invention may be applied in the form of a series of straight conveyors enabling the transporting of the raw material in a container within a neutral atmosphere, preferably created by the injection of precise quantities of water, whereby the steam, at atmospheric pressure will displace air from the process or where the raw materials are portioned or sluiced into, and out of, the auger conveyor. The auger conveyor tube is provided with MW penetrable "windows" that enable the MWP to take place within the closed auger conveyor. The auger conveyor should be lined with, said coated, or produced from MW non absorbing materials so that the spiral, said screw or auger conveyor itself does not absorb MW radiation.

A main advantage of the invention is the possibility for individualised treatment of the raw materials at the different sections or stations allowing auger conveyor with differing contents to be programmed to totally different temperatures; some materials may stay for longer periods of time.

One auger conveyor might, for example, be given a sterilising temperature of 120C while another is exposed during 5 rounds reaching a decomposition temperature of 900C. The gases and vapours emitted from the auger conveyors are led to an initial cooling tower for the straight condensation or fractional condensation of the vapours while the volatile gases may be used as fuel for internal combustion engines or gas turbines after simple rinsing and filtering, or to fuel the direct heating of water or steam.

One or more MW magnetrons may be positioned along the auger conveyor or in or in more than one line along the auger conveyor. This provision will ease the access and exchange of the auxiliary equipment. All the equipment at all stations are anchored identically thus enabling the easy and quick exchange of units with varying programmes and/or easy maintenance of the active stations.

The preferred form, a screw provided with a protective container said tube, is also well suited to prevent leakage of MW into the surroundings.

Several conveyors open up for a doubling ore more of the capacity. In such cases, large quantities of similar raw material requiring practically identical treatment could be run through the conveyors in parallel.

If the raw material is very porous and therefore contains considerable quantities of free air, precise quantities of water may be injected into the central area of the preferably compressed raw material. During the early stages of heating, before the gasification and the vaporisation of the solids, the water will rapidly respond to the MW and the steam will displace about 800 litres of air per litre of water without introducing nitrogen or other gases into the processes. Water will not introduce any undesired alien material that could cause any chemical interactions or complicate those taking place, but, rather, will enable the introduction of dissolved catalysts or other planned chemicals.

The use of auger conveyor may also make the optimal mixing of different raw materials easier, thus improving the end results of the processes.

This method, using auger conveyor, will make it easier both to the use and dose catalysts, whether in liquid, solid or pelletised form, and thus facilitate special or more rapid results in certain processes. It also makes it convenient for one or more stations to be able to inject additives to enhance certain processes.

The use of several auger conveyors in one plant will minimise cleaning and maintenance procedures by making the auger conveyors easily exchangeable, thus making it unnecessary to stop the plant for such procedures. In addition, different residue products may easily be kept separate for subsequent processing, as in the case of ashes containing chromium in waste from the tanning industry.

Claims

1 Apparatus for the reclamation of matter and/or energy from waste or other raw material in solid form or as a liquid in combination with solid material acting as a soaking bed; through the use of microwave induced pyrolysis or evaporation, and comprising an auger within a generally impervious shield, provision to introduce material at or near one end of the auger, means to rotate the auger at will to move material lengthwise within the shield, microwave generating equipment disposed to heat the material as the material moves lengthwise within the shield, provision for the removal of residual solids at or near the other end of the auger, and provision for the extraction of liquid and/or to allow the escape of gas from within the shield, in which the auger and the shield are formed of, or coated with, non-absorbent substances.

2 Apparatus as claimed in claim 1 in which there is a plurality of microwave generating equipment disposed along the length of the shield.

3 Apparatus as claimed in claim 2 in which there are individual controls to regulate the electrical power supplied to at least two of the plurality of microwave generating equipment.

4 Apparatus as claimed in any one of the preceding claims in which the position of the microwave generating equipment can be changed relative to the shield.

5 Apparatus as claimed in claim 4 in which there are standard fitments on the outside of the shield whereby different arrangements of microwave generating equipment or other ancillary machinery can be fixed relative to the shield.

6 Apparatus as claimed in any one of the preceding claims in which there is means to control the speed of rotation of the auger.

7 Apparatus as claimed in any one of the preceding claims in which there is means to control the direction of rotation of the auger.

8 Apparatus as claimed in any one of the preceding claims, in which there is means to introduce controlled quantities of water to the material before the material is introduced to the auger.

9 Apparatus as claimed in any one of claims 1 to 7, in which there is means to introduce controlled quantities of water to the material at or near the provision to introduce material to the auger.

10 Apparatus as claimed in any one of the preceding claims, in which there is means to add catalysts in solid, pelletized or liquid form to material entering the auger, where by the catalysts are mixed with the material by the action of the auger.

11 Apparatus as claimed in any one of the preceding claims, in which discrete parts of the shield are formed of a substance which is transparent to the passage of microwaves.

12 Apparatus as claimed in any one of the preceding claims, in which there is provision to sluice out processed material from the auger and the shield surrounding the auger.

13 Apparatus as claimed in any one of the preceding claims, in which two or more such apparatus are arranged to run in parallel.

14 Method for the reclamation of matter and/or energy from waste or other raw material in solid form or as a liquid in combination with solid raw material, acting as a soaking bed, comprising the steps of feeding the material to an auger within a generally impermeable shield at or near one end of the auger, the auger and the shield being formed of, or coated with, non absorbent substances, rotating the auger to move the material lengthwise within the shield, applying microwave energy to heat the material as the material moves lengthwise within the shield, removing residual solids from the shield at the other end of the auger, and extracting liquid and/or allowing the escape of gas from within the shield.

15 Apparatus substantially as hereinbefore described by way of example with reference to, and as shown in, the accompanying drawings.

16 Method substantially as hereinbefore described by way of example with reference to the accompanying drawings.

13

Application No: GB0425957.8 **Examiner:** Dr Paul Minton

Claims searched: 1-16 **Date of search:** 14 April 2005

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1,2,8,9,12,14	GB 2110803 A (HENRY BALFOUR AND CO) see particularly lines 57-106, page 1, lines 6-18 & 36-42, page 2, and Figure 1.
X	1,6,11,12,14	US 5869817 A (ZIETLOW) see particularly lines 49-67, column 7, lines 19-24, column 8, lines 18-32, column 9, lines 44-52, column 16, and Figures 1A, 1B & 1C.
X	1,6,11,12,14	CA 2038651 A (LAW) see particularly lines 3-16, page 4 and Figure 1.
X	1,2,11-13	GB 2254801 A (LITTLE) see particularly line 30, page 3 to line 6, page 4 and Figure 1.
X	1,6,11,12,14	US 4608261 A (MACKENZIE) see particularly lines 1-20 & 33-39, column 2, lines 12-16 & 51-52, column 3, and Figure 1.
X	1,2,6,11,12,14	US 5400524 A (LECONTE et al) see particularly lines 24-31, column 3, lines 45-54, column 4, and Figures.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[X] :

B8A; H5H

Worldwide search of patent documents classified in the following areas of the IPC[07]

B65G; H05B

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC